(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 961 135 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
01.12.1999 Bulletin 1999/48

(51) Int. Cl.^{6}: **G01S 15/89**

(21) Application number: **98105805.0**

(22) Date of filing: **30.03.1998**

(84) Designated Contracting States:
AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

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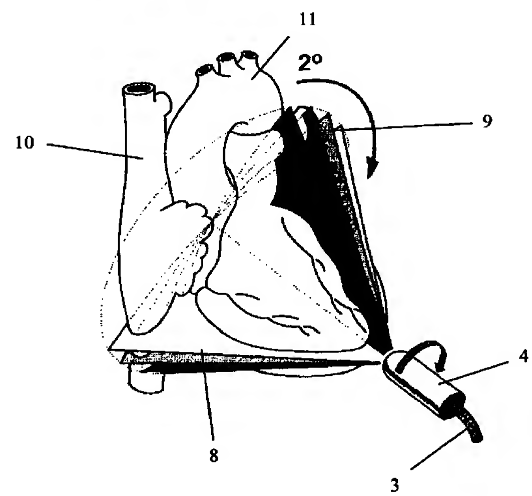
(54) Method and apparatus for ultrasound image acquisition

(57) The present invention incooperates a method and an apparatus for obtaining three-dimensional ultrasound, especially echographic images that allows the three-dimensional reconstruction of anatomic structures. Since prior art techniques teach time-consuming procedures the present invention focuses on a rapid 3-D acquisition of dynamic and quantitative characteristics of human tissues to facilitate the diagnosis of unknown and complex pathology. An object (1), like the heart of a human being is scanned by two-dimensional image scanning means (4) to acquire cross-sectional images (7). The image scanning means (4) are moved in predetermined increments for a predetermined number of times, while scanning said object (1). After the digitalization and recording of said cross-sectional images (7), together with their corresponding positions, said cross-sectional images (7) are transformed into a three-dimensional data set by detecting the contours (14) of said object (1) within said cross-sectional images (7) and by creating a wireframe volume model (22) which represents the outer surface of said object (1) in a three-dimensional manner. Such wireframe volume model (22) is created by linking predefined contour points (19) or 3-D coordinates of said object (1) throughout e.g. an interpolation algorithm. For obtaining suitable wire-frame models (22), a full 3-D acquisition of the object (1) is obsolete by achieving at the same time good dynamic and quantitative information of said object (1) in a very short time.

Fig 2



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Description

[0001] The present invention incorporates a method and an apparatus for obtaining three-dimensional ultrasonic, especially echographic images that allows the three-dimensional reconstruction of anatomic structures according to patent claims 1 and 11.

[0002] Three-dimensional imaging constitutes a major research goal since correct spatial structure information could help to overcome the difficult process of mental conceptualization from cross-sectional images of cardiac structures, pathology of unknown morphology and complex geometrie. Since the intro-duction of tomographic imaging techniques, several directions have been followed in three-dimensional ultrasound.

[0003] Presently, methods and apparatus are known for the acquisition of a consecutive series of cross-sectional images using currently available standard ultrasonic transducers and retro-spective „off-line" three-dimensional reconstruction. This approach necessitates the simultaneous registration of the accurate spatial position and timing of the cross-sectional images if the object under examination is in motion and if such object is to be reconstructed dynamically.

[0004] In order to acquire such sectional images of internal tissues of human beings a piezoelectric transducer is used which con-tains an echographic probe. According to prior art (US 5 159 931) a sector-scan-transducer emits the beam of ultrasound, rotates through an angle of about 180°, with intermediate angular increments having a predetermined amplitude and frequency, around the longitudinal axis of the probe, while the latter remains fixed relative to the examined anatomic structure, there being provided means for the actuation and the control of the rotation of the scanning plane. Hence, during the rotation of the transducer a series of cross-sectional images is acquired which represent different cut planes of the object under examination. The smaller the angle steps of the rotated transducer are the more cross-sectional images can be acquired and the better will be the three-dimensional reconstructed image of the internal tissue of a human being.

[0005] Positional information can be obtained with a mechanical articulated arm, an acoustic (spark gap) and magnetic location system allowing unrestricted (freehand) scanning from any available precordial acoustic window using standard trans-ducers. Scanning techniques using a predetermined geometric acquisition pattern (linear, fan-like and rotational) allow for the recording of closely and evenly spaced cross-sectional images.

[0006] After the acquisition of such a serie of cross-sectional images such images are digitalized and recorded together with their corresponding positions in order to process those images later on.
The recorded cross-sectional images are transformed by a transformation process into a three-dimensional data set which may be displayed later on on a display to allow doctors the diagnosis of complex diseases of the internal tissue or object.

[0007] To realize a geometrical transformation process volume-rendering algorithms are used providing grey-scale-tissue information in the reconstructions and represents a significant advance in three-dimensional echocardiography. Such echocardiographic examinations will be performed with computer-controlled transducer systems and standardized for specific conditions. In order to investigate the shape, volume, size or motion of the heart of a human being, prior art techniques prosecuted a complete three-dimensional acquisition by rotating the transducer in small angle steps calculating a large number of thereby acquired cross-sectional images and by achieving a datacube with the whole three-dimensional image information and displaying such datacube on a suitable display. If the acquisition is a triggered image acquisition the result is a datacube with time information (compare Fig. 1).

[0008] Out of this datacube it is possible to extract cut planes. The orientation in space and the orientation between the cut planes are known from the acquisition method. Here, by the acquisition of a fully three-dimensional reconstruction of the internal tissue it is possible to display different cut planes through the tissue in order to investigate important regions and to detect malfunctions or diseases of the organ.

[0009] Roelandt, Ten Cate, Bruining, Salustri, Vletter, Mumm and Van der Putten: „Transesophageal rotoplane echo-CT - A novel approach to dynamic three-dimensional echocardiography": The Thoraxcentre Journal, Vol. 6/1, 93/94 describe a method and an apparatus of image acquisition, image processing and image display of tissue in order to investigate complex cardiac diseases. They describe the acquisition of sequential cardiac-cross sections together with their spatial position and orientation, the image segmentation (automatic or manual boundary tracing) the realigning and combining of the cross-sections into a three-dimensional structure at either the selected points or throughout the cardiac cycle (dynamically), the interpolation of data „missing" between individual cross-sections and the displaying of three-dimensional images. Here, it is described to use a step-motor via a custom-built wheel-work interface to rotate the control knob of the multiplane probe. The step motor is activated by the steering logic which controls the image acquisition in a given plane by an algorithm considering heart cycle variation by ECG-gating and respiratory cycle variation by impedance measurement. This allows optimal temporal and spatial registration of the cardiac cross-sections. Here, the probe is moved by small angular increments for a predetermined number of times (e.g. 2°, 90 cross-sections per tissue) in order to acquire a full three-dimensional reconstruction.

[0010] However, difficulties in obtaining high quality cardiac tomographic images in multiple orientations by

precordial echocardiography and the time-consuming three-dimensional reconstruction procedure requiring observer tracing of the boundaries of interest are major limitations and have hampered the clinical implementation of three-dimensional echocardiography up to now.

[0011] Additionally, by introducing an endoscope into the vene of a patient implies pain so that the acquisition time should be as short as possible. If the patient is moving during the acquisition or if the respiration is uneven due to the pain arising throughout the endoscope dynamic artefacts diminish the quality of the three-dimensional reconstructed image of the internal organ of the patient.

[0012] Even more, it is sometimes sufficient for the evaluation of a possible organ disease to obtain information about the size, the shape, the volume and the movement of internal organs.

[0013] The object of the invention is to obtain a three-dimensional reconstruction of objects in a more rapid and effective way and to achieve suitable information of the condition of an organ without using the time consuming reconstruction procedures of prior art and without the major limitations of three-dimensional echocardiography incorporated within prior art techniques.

[0014] It is another object of the invention to rapidly acquire dynamic and quantitative information of an internal organ by using low cost apparatus and at the same time facilitating the acquisition methods for non-professionals.

[0015] The objects are solved throughout the characterizing features of claims 1 and 11. Preferable embodiments are claimed within the sub-claims and are further specified as follows:

[0016] The claimed method for obtaining three-dimensional echographic images comprises the steps of scanning an object by two-dimensional image scanning means in order to acquire cross-sectional images of the object. Those image scanning means are moved in predetermined increments for a predetermined number of times or homogeneously along said object (freehand acquisition) while scanning said object and digitalizing each of said cross-sectional images. Those digitalized cross-sectional images are recorded together with their corresponding positions. Those recorded cross-sectional images are transformed into a three-dimensional data set by a transformation process and thereafter displayed on a suitable display.

[0017] A geometrical transformation process incorporates the detection of the contours of said object within said cross-sectional images. Afterwards a wireframe volume model is created which represents the three-dimensional data set by using the respective positions of the cross-sectional images and the respective contours within said cross-sectional images. For the acquisition of a wireframe volume model much less cross-sectional images are necessary than for the acquisition of a full three-dimensional reconstructed image of the tissue.

[0018] Such wireframe volume model is created by linking a contour point of said contours, which represent three-dimensional coordinates, by using surface acquisition or volume rendering techniques. This contour detection is performed by a semi-automatic, automatic or manual contour detection algorithm. The result will be a three-dimensional wireframe which can be displayed in a surface rendering mode or for example as a semi-transparent overlay in a three-dimensional datacube which has been acquired in before. The respective contours of the object under examination can be detected by using grey level ranges followed by the application of noice reduction algorithms, edge enhancement algorithms and/or spatial artifacts reduction algorithms. After such contours have been detected the respective contour points of special interest can be linked with horizontal and vertical wire-lines, preferably with interpolation algorithms, in order to finally represent the wireframe volume model. Alternatively, it is possible to link such contour points, with all adjacent contour points thereby achieving a wireframe model which consists of even triangles representing the three-dimensional surface of the tissue.

[0019] For the acquisition of echocardiographic images of cardiac structures, especially for the acquisition of an image representing the heart of a human being, it is possible to create several wireframe volume models of the same object in motion. Each wireframe volume model represents one condition of the cardiac tissue. By adding the dimension of time for functional assessment these different wireframe volume models can be displayed successively to acquire dynamic or quanti-tative information of the object, thus representing a „moving" wireframe model. Hence, it is possible to measure e.g. quanti-tatively the left ventricular function of the heart, the ejaction fraction or the wall motion. Diseases or malfunctions of the heart can thus be easily detected.

[0020] In order to properly display the successive wireframe models it is necessary to display the three-dimensional data sets in accordance with an algorithm considering heart cycle variations by ECG-gating and respiratory cycle variations by impedance measurements. A rotoplane echo-CT wireframe acqui-sition method comprises the moving of the image scanning means in predetermined angular increments by only acquiring the most important cut planes of the tissue under examination (e.g. for a left ventricle rotation acquisition ever 30° rot angle) for a predetermined number of times to record each of such cross-sectional images and its corresponding angular position and to detect the contours of the object within said cross-sectional images with respect to a common rotation axis of said cross-sectional images.

[0021] Additionally, it might be useful to record one or more cross-sectional images from cut planes of the object which are substantially orthogonal to said angu-

lar positioned cross-sectional images by relocating the transducer to another place or by using another e.g. handheld-transducer (Fig. 7). Consequently, it is easier to link the respective contour points by specifying special contour points represented by the cross-sections of a roto plane (angular cross-section) and an orthogonal cut plane (relocated acquired cross-section) .

[0022] The corresponding apparatus for obtaining three-dimensional echographic images comprises two-dimensional image scanning means for scanning an object in order to acquire cross-sectional images of said object and means for moving that image scanning means in predetermined increments for a predetermined number of times or homogeneously along said object. Digitalization means digitalize the acquired cross-sectional images and recording means record these digitalized cross-sectional images and their corresponding positions. Afterwards transforming means transform these cross-sectional images into a three-dimensional data-set by a geometrical transformation process wherein such three-dimensional data set is then displayed by displaying means. The geometrical transformation process comprises detecting means for detecting the contours of said object within said cross-sectional images by implementing an incremental or dynamic threshold to differentiate lighter or darker sections of the grey leveled ultrasonic image. Volumetric acquisition means thereafter create a wireframe volume model by using the positions of the respective cross-sectional images and the detected contours or contour points which represent three-dimensional coordinates within said cross-sectional images.

[0023] If the image scanning means are incrementally moved the apparatus further incorporates a step-motor and a steering logic to control the incremental acquisition of cross-sectional images of the object. Furthermore, the two-dimensional scanning means comprise a position sensor for detecting the position of the respective cross-sectional images which is important for a freehand acquisition by moving the transducer homogeneously along the object under examination.

[0024] For the dynamic acquisition the apparatus further comprises ECG-gating means and respiration trigger means for dynamically scanning cardiac objects in order to be able to display the moving tissue in motion in cine-loop format.

[0025] A preferred embodiment of the present invention and a routine cardiac ultrasound examination, rapid three-dimensional acquisition method will be explained in conjunction with the drawings as follows:

Fig. 1 shows an endoscope echocardiographical acquisition,

Fig. 2 shows the principle of acquisition of sequential cross-sectional images of a heart,

Fig. 3 shows rotated cut planes,

Fig. 4 shows a cross-sectional image with detected contours,

Fig. 5 shows rotated cut planes with the contour information,

Fig. 6 shows a calculated wireframe volume model,

Fig. 7 shows the average rotation volume acquisition technique,

Fig. 8 shows a freehand ultrasound transducer,

Fig. 9 shows a motor-controlled rotation transducer, and

Fig. 10 shows the transducer of Fig. 8 with a position sensor.

[0026] Fig. 1 shows an object (1) like an internal organ or tissue (e.g. heart) which is scanned by an ultrasonic beam (8) from scanning means (4) like a transducer which is incorporated within a probe situated in a vene or artery adjacent to the object (1 wherein the scanning means (4) are linked with processing means (not shown) by an endoscope connection (3) within the endoscopical path (2) (e.g. vene or artery) . The transesophageal probe (4) houses e.g. a 5 MHz 64-element rotational-array transducer at the distal end of a standard gastroscope or endoscope. The dimensions of the multiplane probe (4) are e.g. 14 mm width, 10,3 mm thickness and 40 mm length. The scanning plane can be continuously rotated through 180° starting from a longitudinal imaging position via a control knob on the handle of the echoscope. The cardiac cross-sections encompass a cone shaped volume with its point originating in the transducer (compare also Fig. 2). After positioning in the esophagus the probe (4) can be kept in a steady position by locking the antero-posterior flexion control in the anterior position.

[0027] Then a step motor is activated and mechanically rotates the probe (4) which allows optimal temporal and spatial registration of the cardiac cross-sections.

[0028] The step motor is activated by the steering logic which controls the image acquisition in a given plane by an algorithm considering heart cycle variation by ECG-gating (5) and respiratory cycly variation by impedence measurement. For each position of the heart (e.g. systole oder diastole) the heart is scanned by acquiring a series of cross-sections (6), thereby obtaining a set of cross-sectional images (7) which belong to a certain position of the heart (stroposcopical picture) .

[0029] When a cardiac cycle is selected by the steering logic the cardiac cross sections (6) are sampled at

e.g. 40 msec intervals during a complete heart cycle, digitized and stored in the computer memory. Then, the step motor is activated and rotates the control knob 30° to the next cross-section (6) where the same steering logic is followed. To encompass the whole heart (or region) six sequential standardized cross-sections from 0-180° must be obtained each during a complete heart cycle.

[0030] Fig. 2 shows an enlarged few of the principle of acquisition of sequential cross-sections (6) from the apical transducer position. A transducer (4) being linked to the computer by an endoscope connection (3) scanns the heart (1) consisting of the right ventricle (10) and the left ventricle (11) by acquiring a couple of acquisition planes (9) troughout the ultrasonic beam (8).

[0031] During the acquisition phase the cardiac cross sections are digitized and stored in the computer memory. In the post-processing phase they are formatted in the correct sequence (compare Fig. 1) according to their ECG-phase in volumetric data sets.

[0032] Fig. 3 shows four rotated cut planes (12a, 12b, 13a, 13b) being rotational positioned around a common rotation axis (15) .

[0033] Fig. 4 shows a cross-section (6) with a contour (14) which is based on contour points (17) thus defining a contour surface (16) . These contour points (17) are connected with a spline-interpolation algorithm. If the object is not in the rotation axis (15) it is possible to define a new rotation axis (15).

[0034] A grey level range is used to separate cardiac structures from the bloodpool and background in each cross-section (6) followed by the application of several algorithms to reduce noise, to enhance edges and the reduction of spatial artifacts (ROSA filter). Thus, the contour (14) can be defined.

[0035] Fig. 5 shows rotated acquisition planes (9) representing the above specified cut planes (12a, 12b, 13a, 13b) being positioned around a common rotation axis (15) together with the contour information (14) being detected in before. A 3D-data cube (18) is hence virtually situated among the acquisition planes (9).

[0036] Fig. 6 shows the calculated wireframe volume model (22) with the contour points (19), horizontal wirelines (20) and vertical wirelines (21). The calculated contour points (17, 19) reperesent 3D-coordinates within such wire-frame volume model (22) and have to be linked by surface acquisition or volume rendering techniques. Here, it is possible to link each contour point (19) with all adjacent contour points thus obtaining a large number of small triangles representing the surface of the wireframe volume model (22) .

[0037] The acquisition method of the present invention requires only a couple of cut planes (12a, 12b, 13a, 13b) a fast and effective detection of contour points (17, 19) and the calculation of the wireframe volume model (22) in order to obtain a good approximation of the object (1) in order to get dynamic, quantitative or shape information.

[0038] Fig. 7 shows a technique for acquiring the volume of the object (1) . The rotation axis (15) of a cross sectional image (7) is defined through the centre of the object (1) . About the rotation axis (15) N acquisition planes (9) or cutplanes (12a, 12b, 13a, 13b), incooperating the respective cross-sectional images (7), are defined with respect to the previous (Fig. 2) acquisition. Each plane represents a rotation of 180/N degrees with respect to the previous cutplane. A contour (14) with contour points (17) is defined for each cross-sectional image (7). The rotation axis (15) cuts each cross-sectional image (7) in two. In order to acquire the volume of the object (1), the method calculates the rotation volumes V(1...2N) for both parts of each cross-sectional image (7). The rotation volume V is defined by a segment (S), consisting of the rotation axis (15), the contour (14) of one half of a cross-sectional image (7) being rotated about 180/N degrees (r_1, r_2, r_3, ... r_N) until the contours (14) of the next cross-sectional image (7), the next cutplane (9), is reached. To be more precise it is also possible to rotate only segments (25) of one part of a cross sectional image (7), those segments (25) being defined by 2 successively situated contour points (17) of said contour (14) and the rotation axis (15). To get the volume of the whole object (1), all rotation volumes of said segments (25) are added.

[0039] For symmetrical rotational objects, only 1 cutplane (9) would be enough to get the exact volume. The exact measurement of the contours (14) depends on the number of contour points (17) which can be increased by using spline curves. The rotation axis (15) should be defined by the largest dimension of the object (1) in order to get good and fast results. The more simple the object (1) is shaped, the smaller the number of cutplanes (9) may be in order to achieve good and fast results. The exact approximation of the volume depends on the number of cuts.

[0040] The same acquisition method is also possible for successively acquired cutplanes (9) linearily along the object (1) by free-hand scanning or machine-controlled scanners. The volume is acquired by moving said contours (14) or segments (25) of said contours (14) within said cross-sectional images (7) along an axis which is substantially perpendicular to said cross-sectional images until the contours (14) of the next cross-sectional image (7), the next cutplane (9), is reached. Here, the movement is not rotational but linear since the cutplanes (9) were successively acquired linearily along the object (1).

[0041] Fig. 8 shows a freehand transducer (4) together with a position sensor (23).

[0042] Fig. 9 shows a rotational transducer (4) as shown in Fig. 2 admitting an ultrasonic beam (8) which is rotating in predetermined incremental steps or homogeneously, thereby scanning the object (1) under examination.

[0043] Fig. 10 shows the transducer (4) of Fig. 8 together with a position sensor (23). The position sen-

sor (23) is useful for detecting the rotation axis (15) if the transducer (4) is slightly moved during the acquisition of the cross-sectional images (7). The information of the position sensor (23) can be computed in order to realigne and to correctly locate the cross-sectional images (7) with respect to each other.

[0044] For the rapid three-dimensional acquisition method of the present invention the following four acquisition methods are possible:

1. A freehand acquisition with the transducer (4) of Fig. 7 and the position sensor (23) is possible by acquiring different cut planes wherein the position sensor (23) supplies the transformation means with the spatial orientation of the different cross-sectional images (7).

2. Furthermore, a triggered freehand acquisition is possible wherein a transducer (4) together with a position sensor (23) is used which is the same method as described above but with an ECG- and respiration triggered acquisition.

3. A motor controlled rapid acquisition with a rotational transducer (4) as shown in Fig. 8 and 9 is feasable as well as

4. a motor controlled rapid acquisition together with a position sensor (23). The position sensor (23) enables the acquisition apparatus to locate the proper rotation axis (15) so that movements of the rotational ultrasound probe (4) do have no influence on the image calculation.

[0045] The rapid three-dimensional aquisition method of the present invention is also feasable for color Doppler examination as follows:

[0046] In the routine cardiac ultrasound examination the doctor evaluates the disease of Mitral Valve Regurgitation (MR), Aortic Valve Regurgitation (AR), Mitral Valve Stenosis (MS), Aortic Valve Stenosis (AS) etc. using color Doppler examination. These patients have a very fast and turbulent blood flow (Jet flow) . Normally Jet flow is represented by a mosaic pattern in the color Doppler image. The doctor examining the patient tries to visualize the biggest Jet flow by changing the probe position. In the routine the echo doctor evaluates the severity of disease by measuring the area (e.g. regurgitant area) of Jet flow (mosaic pattern) . This evaluation is done by only one cut plane. By using a three-dimensional color flow acquisition using a freehand scan method it is possible to evaluate the valvular disease more accurately that means closer to the actual flow information even if errors occure.

[0047] The procedure is done as follows:

1. The biggest Jet flow is visualized by using the color Doppler mode.

2. At the same transducer probe position one cardiac cycle is acquired by using a freehand scan method together with ECG-gating.

3. The transducer probe is rotated to a certain degree and another cardiac cycle is acquired. These acquisitions are continued several times in order to obtain 2-20, preferably 3-6, cardiac cycle slices.

4. During the acquisition the rotation axis and the position of the probe will be inclined wherein all angular and positional information will be recorded together with the colour Doppler images.

5. The rotation axis is compensated or realigned for each image (each phase) to the first position of the biggest Jet flow.

6. The best phase for the evaluation is selected.

7. A manual, semi-automatic or automatic detection of the Jet flow area (mosaic pattern) or the border of each image is conducted.

8. The three-dimensional color flow volume is calculated and the severity of the valvular disease is evaluated.

9. Another possibility is to surface render one cardiac cycle color flow image from a certain view by using a wireframe volume model of the present invention.

Claims

1. Method for obtaining three-dimensional ultrasound images, comprising the steps of

- scanning an object (1) by two-dimensional image scanning means (4) to acquire cross-sectional images (7) of said object (1),
- moving said image scanning means (4) in predetermined increments for a predetermined number of times or homogeneously along said object (1), while scanning said object (1),
- digitalizing each of said cross-sectional images (7),
- recording each of said cross-sectional images (7) and its corresponding position,
- transforming said cross-sectional images (7) into a three-dimensional data set by a transformation process, and
- displaying said three-dimensional data set,

characterized by
realizing said transformation process by

- detecting the contours (14) of said object (1) within said cross-sectional images (7), and

- creating a wireframe volume model (22) as said three-dimensional data set using said positions of said cross-sectional images (7) and said contours (14) within said cross-sectional images (7).

2. Method as claimed in claim 1, **characterized by** linking contour points (19) of said contours (14) by using surface acquisition and/or volume rendering techniques.

3. Method as claimed in claim 2, **characterized by** linking contour points (19) of said contours (14) with horizontal and vertical wire lines (20, 21), preferably with an interpolation algorithm.

4. Method as claimed in claim 2, **characterized by** linking contour points (19) of said contours (14) by linking each of said contour points (19) with all adjacent contour points (19).

5. Method as claimed in claim 2, **characterized by** moving or rotating said contours (14) or segments (25) of said contours (14) within said cross-sectional images (7) along an axis, being substantially perpendicular to said cross-sectional images (7), or about a common rotation axis (15) of said cross-sectional images (7) until the contours (14) of the next cross-sectional image (7) are reached.

6. Method as claimed in one of the preceeding claims, **characterized by** detecting the contours (14) of said object (1) by using grey level ranges, followed by the application of noise reduction algorithms, edge enhancement algorithms and/or spatial artifacts reduction algorithms.

7. Method as claimed in one of the preceeding claims, **characterized by** creating several wireframe volume models (22) of an object (1) in motion and displaying said three-dimensional data sets, which correspond to said wireframe volume models (22), successively, to acquire dynamic and/or quantitative information of said object (1).

8. Method as claimed in claim 7, **characterized by** creating several wireframe volume models (22) of a cardiac object (1) in motion and displaying said three-dimensional data sets in accordance with an algorithm considering heart cycle variations by ECG-gating and respiratory cycle variations by impedance measurements.

9. Method as claimed in one of the preceeding claims, **characterized by**

   moving said image scanning means (1) in predetermined angular increments for a predetermined number of times,
   recording each of said cross-sectional images (7) and its corresponding angular position, and
   detecting the contours (14) of said object (1) within said cross-sectional images (7) with respect to a common rotation axis (15) of said cross-sectional images (7).

10. Method as claimed in claim 9, **characterized by** additionally recording one or more cross-sectional images (7) from cutplanes (16) of said object (1) which are substantially orthogonal to said angular positioned cross-sectional images (7).

11. Apparatus for obtaining three-dimensional echographic images, comprising

- two-dimensional image scanning means (4) for scanning an object (1) to acquire cross-sectional images (7) of said object (1),
- means for moving said image scanning means (4) in predetermined increments for a predetermined number of times or homogeneously along said object (1),
- digitalization means for digitalize each of said cross-sectional images (7),
- recording means for recording each of said cross-sectional images (7) and its corresponding position,
- transforming means for transforming said cross-sectional images (7) into a three-dimensional data set by a geometrical transformation process, and
- displaying means for displaying said three-dimensional data set,
  characterized in that
  said geometrical transformation process comprises
- detecting means for detecting the contours (14) of said object (1) within said cross-sectional images (7), and
- volumetric acquisition means for creating a wireframe volume model (22) using said positions of said cross-sectional images (7) and said contours (14) within said cross-sectional images (7).

12. Apparatus as claimed in claim 11, **characterized in that** said means for moving said image scanning means

(4) incooperate a step motor and a steering logic which control the incremental acquisition of cross-sectional images (7) of said object (1).

13. Apparatus as claimed in claim 11 or 12, **characterized in that** said two-dimensional image scanning means (4) comprise a position sensor (23) for detecting the positions of said cross-sectional images (7).

14. Apparatus as claimed in one of the claims 11 - 13, **characterized in that** said apparatus further comprises ECG-gating means and respiration trigger means for dynamically scanning cardiac objects (1).

Fig 1

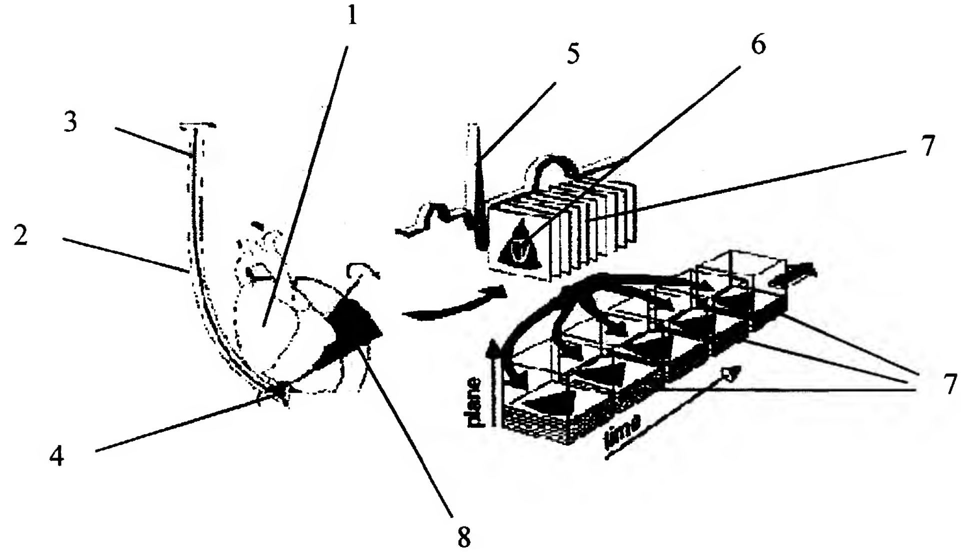


Fig 2

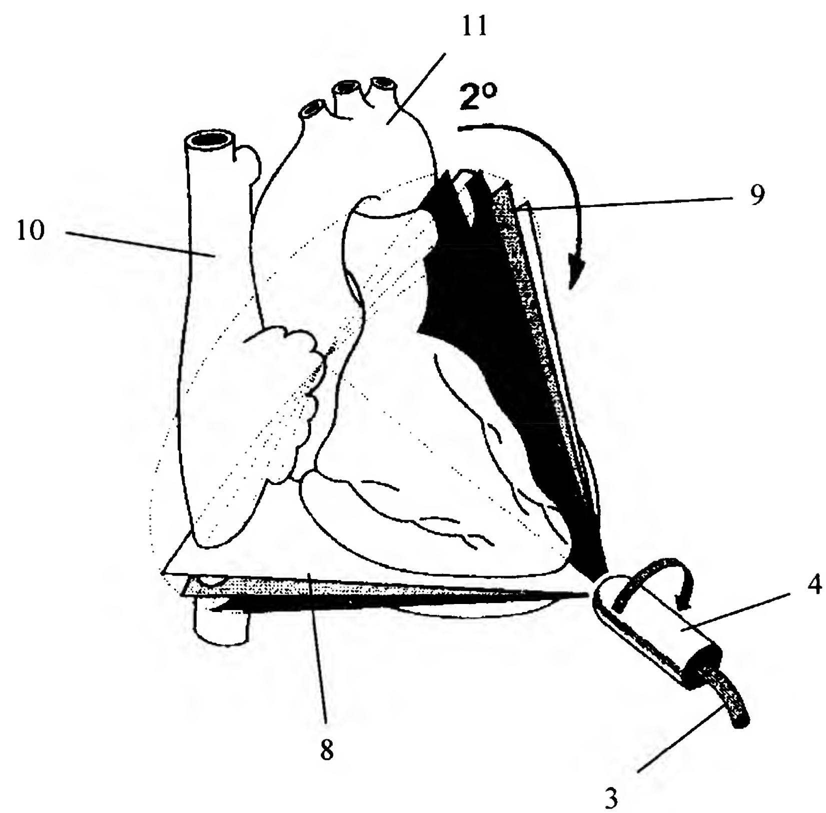


Fig 3

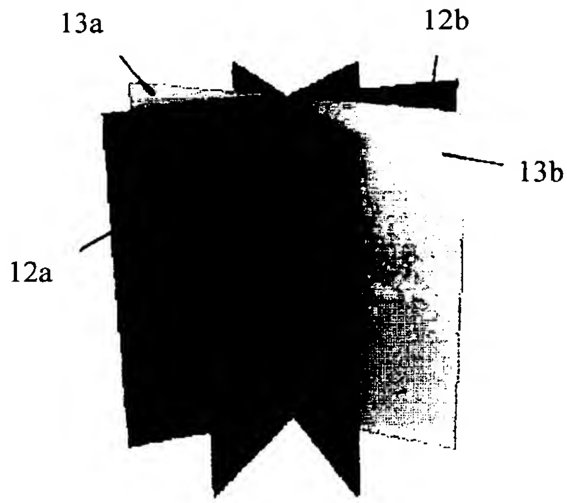


Fig 4

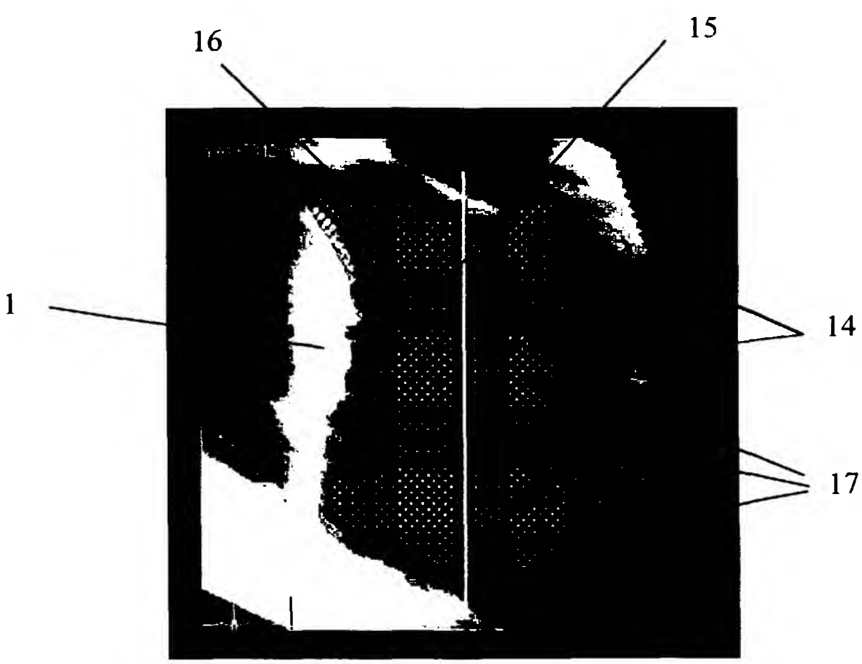


Fig 5

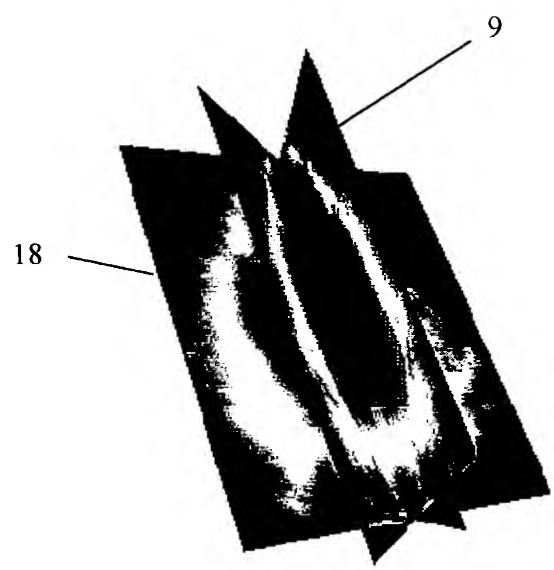


Fig 6

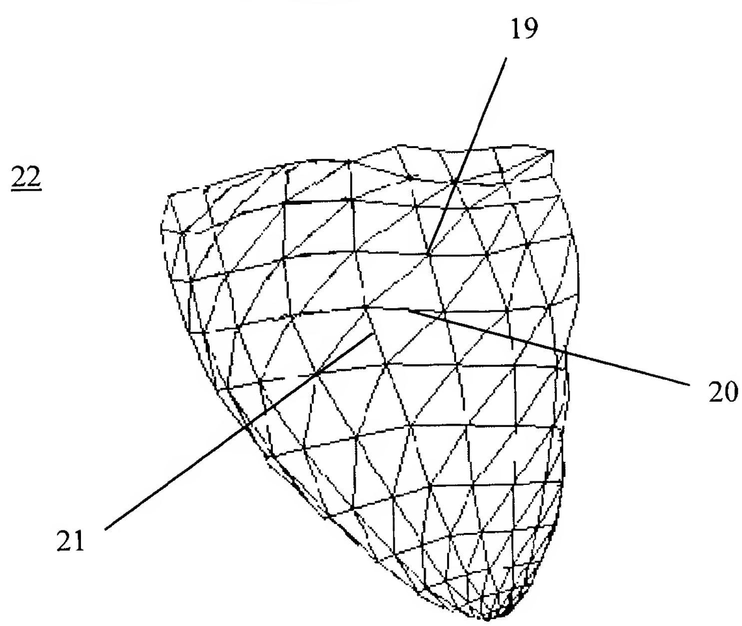


Fig 7

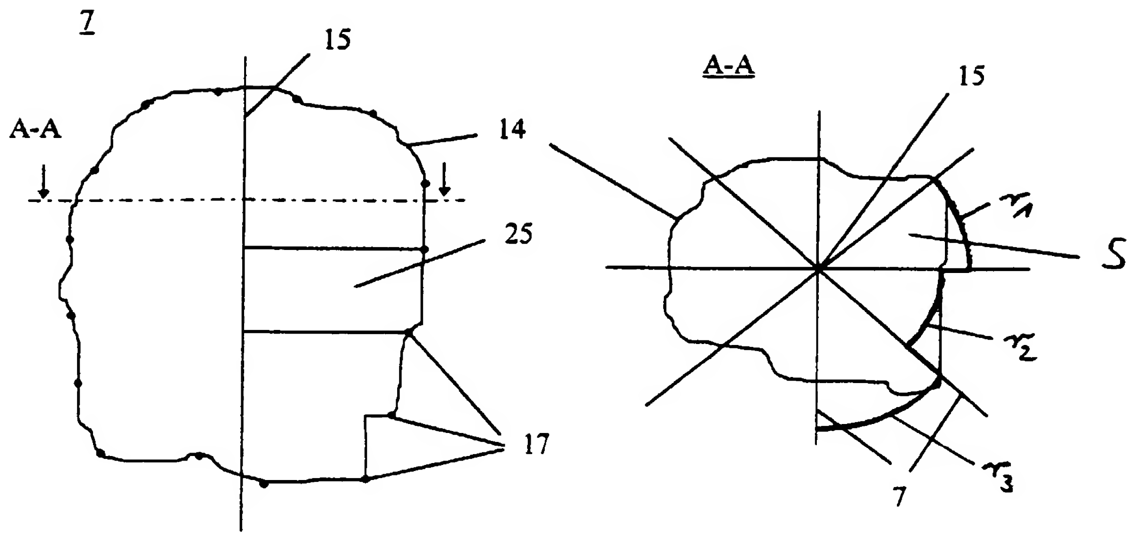

7
15
A-A
14
25
17
A-A
15
r_1
S
r_2
7
r_3

Fig 8

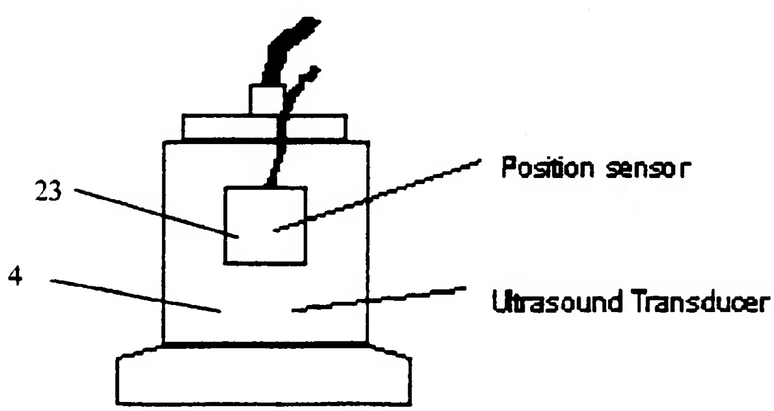

23
Position sensor
4
Ultrasound Transducer

Fig 9

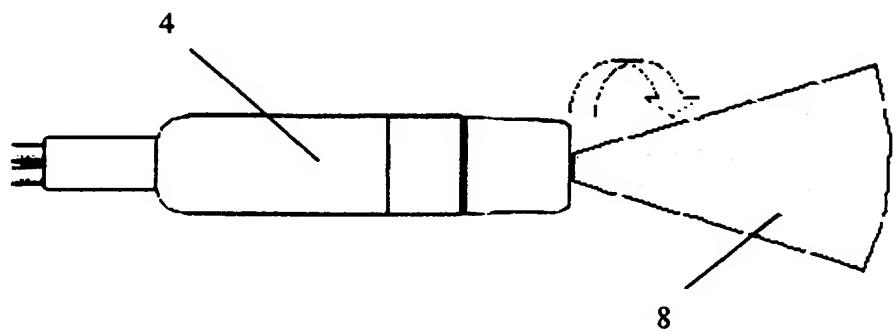
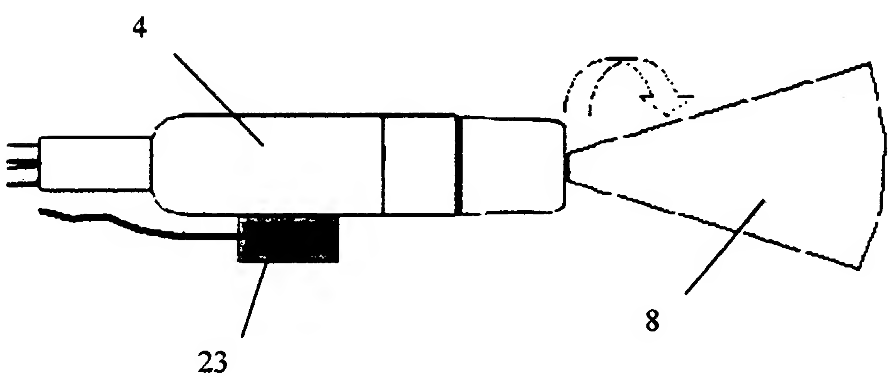


Fig 10



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EUROPEAN SEARCH REPORT

Application Number
EP 98 10 5805

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G01S
A61B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	13 July 1998	Danielidis, S

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